800MHz auction format and software

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Auction format

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Combinatorial Clock Auction Format

- **Principal Stage** – determines the generic lots assigned to each bidder
  - **Primary rounds** – clock auction format
    - Succession of rounds where auctioneer announces prices and bidders specify their demand (subject to activity rules);
    - If there is excess demand, further rounds may be run, with prices of lot categories in excess demand increasing
    - Primary rounds will end when there is no excess demand in any lot category
  - **Supplementary round** – sealed bid round
    - Bidders may submit multiple mutually exclusive supplementary bids;
    - Bid amounts are subject to constraints that depend on bids submitted during the primary rounds
- **Assignment Stage** – determines specific frequencies to be assigned to each winner (required if more than one winner of B lots only)

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Eligibility

- Each lot in the auction is assigned a number of eligibility points
  - Spectrum Eligibility Points (SEP): 1 SEP per 2x5MHz; and
  - Exemption Eligibility Points (EEP): 1 EEP per exemption in a coverage area
- Exemption Eligibility is spectrum package specific:

EEP_A2B	EEP_4B	EEP_AB	EEP_3B	EEP_A	EEP_2B	EEP_B
3	1	3	3	1	3	3

- All qualified bidders will start the auction with identical initial eligibility – EEP as in the table above and 4 SEP reflecting the spectrum cap of 2x20MHz

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Activity rules

- Bidding in the primary rounds is subject to an eligibility-based activity rule:
  - Bidders start the auction with a given level of eligibility
  - In each primary round, bidders may only bid for combinations of lots adding to a total eligibility that does not exceed their eligibility
  - In each primary round after the first round, the bidder eligibility will be adjusted to reflect their bid in the previous round
    - For spectrum eligibility, the eligibility is set to the total eligibility of spectrum lots bid for in the previous round
    - There are separate categories for exemption lots, and the adjustments depend on the spectrum lots bid for in the previous round
- Each time a bidder loses eligibility during the primary rounds, this will set some constraints on the supplementary bid amounts that the bidder may submit, to reflect the price differences prevailing in the round where the bidder made such choices – we call these the **relative caps on supplementary bids**
- A bidder's choice of final primary round package will also set some constraints on the supplementary bid amounts that the bidder may submit

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Relative caps on supplementary bids

- The bid amount for the package a bidder bids for in the final primary round is uncapped (except if the bidder has bid for a package containing no lots)
- Supplementary bids for any other package is subjected to a relative cap, determined by the bidder's choice in the last round where the bidder would have been able to bid for that package, calculated using a revealed preference approach, as follows:
  - Suppose the bidder was last able to bid for package X in round n, and bid for package Y instead.
  - Let $(X\text{-}Y)\cdot p_n$ be the price difference between X and Y in round n (when the bidder made the choice to bid for Y instead of X)
  - Let $B(Y)$ be the highest bid that the bidder submits for package Y (either during the primary rounds or in the supplementary bids round)
  - The bid amount that the bidder may specify for package X will then be constrained to its highest bid for package Y (which the bidder preferred at the prices prevailing in round n when the bidder made its choice of Y over X) plus the price difference at the time of making that choice – therefore the relative cap on X is: $B(Y)+(X\text{-}Y)\cdot p_n$
- Note that:
  - Where the bidder had sufficient eligibility to bid for X in the final primary round, then round n is the final primary round
  - If package Y is the zero package, then the cap on the bid amount for X is the price of X in round n

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Relative caps example

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		A	B	E1	E2	E3	SEP	EEP_4B	EEP_A2B	EEP_3B	EEP_AB	EEP_2B	EEP_A	BBP_B
Round 1	Round price (DKK)	50m	50m	10m	10m	10m	4	1	3	3	3	3	1	3
	Bid	0	4	1	0	0								
Round 2	Round price (DKK)	60m	60m	20m	20m	20m	4	1	3	3	3	3	1	3
	Bid	0	4	0	0	0								
Round 3	Round price (DKK)	60m	70m	20m	20m	20m	4	0	3	3	3	3	1	3
	Bid	0	3	1	1	0								
Round 4	Round price (DKK)	70m	80m	30m	30m	30m	3	0	3	2	3	3	1	3
	Bid	1	1	1	1	1								
Round 5	Round price (DKK)	80m	90m	35m	35m	30m	3	0	3	2	3	3	1	3
	Bid	0	2	0	0	0								
Round 6	Round price (DKK)	80m	120m	35m	35m	30m	2	0	3	2	3	0	1	3
	Bid	0	0	0	0	0								

Relative caps

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Constrained Package X	Constraining Package Y	Constraining Round n	Highest bid for Y (DKK)	Price difference between X and Y in round n (DKK)	Cap (DKK)
A2B	3BE1E2	3	250m	-50m	200m
4BE1	4B	2	240m	20m	260m
3BE1E2E3	3BE1E2	3	250m	20m	270m
3BE2E3	2B	5	180m	155m	335m
3BE1E2	2B	5	180m	160m	340m
2BE1	2B	5	180m	35m	215m
2B	Zero package	6	0	240m	240m
BE1E2E3	Zero package	6	0	220m	220m

Coverage obligation

- **Required non-exempt bids**: In order to be allowed to bid for a package that includes any exemptions from the coverage obligation, the bidder has to bid at least reserve prices for the corresponding spectrum package without any exemptions
- The auction outcome is restricted to those where the coverage obligation in a coverage area is assigned if suitable spectrum for meeting the obligation is assigned
- The determination of excess demand, winners and prices paid has to reflect this constraint

Winner determination

- The winner determination process selects a combination of bids that maximises total bid value subject to:
    - Accepting at most one bid from each bidder
    - Allocating no more lots than are available (including exemptions lots whose supply is endogenously determined by the number of winners of A and B lots)
- If there are multiple combination of bids that maximises total bid value, a tie break rule is applied in the following order:
    1. Combination with most winners
    2. Combination with most exemption lots awarded
    3. Combination with minimum unsold spectrum lots
    4. Combination with most winners subjected to a coverage obligation
    5. Combination with most clock-compatible bids when assessed against the primary bids submitted in the last primary round
    6. Random

Winner determination

Bid ID	Bidder	A	B	E1	E2	E3	Bid Amount
1	Bidder1	0	2	0	0	1	DKK250m
2	Bidder1	0	2	0	0	0	DKK150m
3	Bidder2	0	3	0	1	0	DKK300m
4	Bidder2	0	3	0	0	0	DKK150m
5	Bidder3	1	0	1	0	0	DKK60m
6	Bidder3	1	0	0	0	0	DKK50m

Tied outcomes (DKK210m)
Tie 1: 2&5
Tie 2: 4&5

Both outcomes share the same total bid value, therefore winning outcome will be determined in accordance to the tie-break rules:
1. Combination with most winners – identical in both ties, 2 winners each
2. Combination with most exemptions awarded – identical in both ties, 1 exemption awarded each
3. Combination with fewer unsold spectrum lots – Tie 1 has 2 unsold B lots while Tie 2 only has 1 unsold B lot. Therefore, our winning combination of bids is Tie 2, bid 4 and bid 5 are winning bids.

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Determination of excess demand at the end of a primary round

- At the end of each primary round, a **provisional winner determination** is run on all bids received in the auction up to that point (there may be multiple solutions)
- If it is possible to select an optimal set of bids in which all bidders receive *at least* as many lots as they demanded at prevailing round prices, then there is **no excess demand**
- However, if in any provisional winning outcome, a bidder does not receive as many lots in a lot category as it demanded in the prevailing primary round, then there is **excess demand** in that lot category
- If there is excess demand, a further round may be run, with higher prices for lot categories in excess demand

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Determination of excess demand

Bid ID	Price	A (DKK50m)	B (DKK50m)	E1 (DKK10m)	E2 (DKK10m)	E3 (DKK10m)	Bid Amount
1	Bidder1's Primary Bid	0	2	0	0	1	DKK110m
2	Bidder1's RNEB	0	2	0	0	0	DKK100m
3	Bidder2's Primary Bid	0	2	0	1	0	DKK110m
4	Bidder2's RNEB	0	2	0	0	0	DKK100m
5	Bidder3's Primary Bid	1	1	1	0	0	DKK110m
6	Bidder3's RNEB	1	1	0	0	0	DKK100m

Provisional winning outcomes

Tie 1: Bid 1&3 → Bidder3 does not win any lots in this provisional winning outcome, so its demand for lot categories A, B and E1 cannot be met

Tie 2: Bid 1&5 → Bidder2 does not win any lots in this provisional winning outcome, so its demand for lot categories B and E2

Tie 3: Bid 3&5 → Bidder1 does not win any lots in this outcome, so its demand for lot categories B and E3 cannot be met

There is excess demand in all lot categories

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Base prices

- Each winner has to pay a **base price** for its winning bid
- Base prices are required to satisfy the following properties:
    - The base price will be at least the package reserve price and no higher than the winner's winning bid
    - The sum of base prices that apply to any subset of winners needs to be at least the opportunity cost of assigning those winners the lots included in their winning bids (i.e. no other combination of bidders has offered to pay more for these lots)
    - Subject to the restrictions above, the total sum of base prices is *minimised,* in order to reduce incentives for bidders to shade their bids
- We calculate the opportunity cost of a subset of winners as the difference between:
    - The value of bids that would be selected as winning bids if any bids from winners in the subset are excluded except their non-exempt bids, which are included at reserve prices; and
    - The value of winning bids in the original auction outcome from winners not included in the subset

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Calculating base price in our previous example

Bid ID	Bidder	A	B	E1	E2	E3	Bid Amount
1	Bidder1	0	2	0	0	1	DKK250m
2	Bidder1	0	2	0	0	0	DKK150m
3	Bidder2	0	3	0	1	0	DKK300m
4	Bidder2	0	3	0	0	0	DKK150m
5	Bidder3	1	0	1	0	0	DKK60m
6	Bidder3	1	0	0	0	0	DKK50m

Bidder 2 won 3B lots with its bid of DKK150m while Bidder 3 won the A lot and E1 with its bid of DKK60m. The total value of winning bids is DKK210m.

Considering only non-exempt bids from Bidder 2, the optimal combination of bids that yield the highest total bid value of DKK210m is the set of bid4 and bid5 or the set of bid2 and bid5.

Considering only non-exempt bids from Bidder 3, the optimal combination of bids that yield the highest total bid value of DKK200m is the set of bid4 and bid6 or the set of bid2 and bid6.

Considering only non-exempt bids from Bidder 2 **and** Bidder 3, the optimal combination of bids that yield the highest total bid value of DKK200m is the set of bid2 and bid6 or the set of bid4 and bid6.

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Calculating base prices

- Individual opportunity cost:
    - Bidder2 = 210 – (210-150) = 150
    - Bidder3 = 200 – (210-60)= 50
- Joint opportunity cost of Bidder2 and Bidder3: 200 – (210-210)= 200
    - This is equal to the aggregate sum of Bidder2 and Bidder3's individual opportunity cost (150+50=200)
    - Therefore, setting base prices for Bidder2 and Bidder3 that are equal to their individual opportunity cost would be sufficient to meet the requirement that they jointly pay no less than their joint opportunity cost
- Bidder2's individual opportunity cost is equal to the reserve price for the package it wins, so we can set its base price to DKK150m
- Bidder3's individual opportunity cost is below the reserve price for the package it wins, therefore the base price for Bidder3 needs to be set to the reserve for its package (DKK60m)

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Auction software

Electronic Auction System (EAS)

- Bidding through EAS over the public internet using a web browser (Internet Explorer, Firefox or Chrome):
  - EAS provides bid forms and information about prices set by the auctioneer and round results
  - Provided that they user remains connected to the EAS, the interfaces will automatically update as the auction progresses – providing relevant page (e.g. bid form during a round)
  - EAS also provides auction history of rounds already completed and approved by the auctioneer, which may also be downloaded
  - Submission of supplementary bids may be done on the interface, and an upload facility for submission of bids from tab delimited text files is also available
- Bid submission process requires two steps:
  - Submission of a decision, which is then checked for validity at the server end;
  - If the decision checked is valid, the bidder may then formally submit that decision (or revert to the bid form if it wishes to amend its decision)
- Failure to submit a bid within the specified round time window may trigger an a round extension (if the bidder has extensions available – each bidder will start the auction with two extension rights for the primary rounds, and one for each the supplementary and the assignment round)
- Hands on trial of the EAS during mock auction, a user manual will also be provided to qualified bidders

Electronic Auction System (EAS)

- An up-to-date version of Java must be installed on the terminal used to access the EAS
- Authentication:
    - Access is controlled by purpose-built user-specific digital certificates distributed by the auctioneer to bidders, which will need to be installed on the terminal used to access the EAS
    - A login password is also required to access the EAS, which will be provided by the auctioneer
    - Different terminals may be used by each user to access the EAS, but only one session at a time is allowed (no parallel logins)
    - Sessions automatically terminated if user loses connection, so that the user may be able to connect from a different terminal
- All requests submitted by users are logged